

DOCUMENT BOOK
Structural Inspection

POST OFFICE SQUARE GARAGE
BOSTON, MASSACHUSETTS

DEC 4436

February 1984

consulting engineers

Simpson Gumpertz & Heger Inc.

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3 March 1984

Mr. Robert Ryan, Director
Boston Redevelopment Authority
1 City Hall Square
Boston, Massachusetts 02201

Comm. 84061 - Structural Inspection of the Post Office Square Garage, Boston, MA

Dear Mr. Ryan:

This letter report summarizes the results of our structural inspection of the Post Office Square Garage. This investigation was described in our proposal to you dated 16 February 1984, and authorized by your letter to us dated 21 February 1984.

Objective and Scope

Our objective is to give you our general opinion about the structural condition of the garage and the effect of observed deterioration on the structural integrity of the garage. Our conclusions are based on a brief review of the structural and architectural drawings; a limited condition survey of the second floor slab; a limited visual inspection of the main parking areas and ramps at the basement, first, second and roof levels; and a limited visual inspection of the exterior of the building.

Background

The Post Office Square Garage, constructed in 1953, is a reinforced concrete parking structure. The building has four parking levels. They are, as designated on the original drawings, the basement, first floor, second floor and roof. The basement is one story below street level and the first floor is at street level.

The basement floor is a 6 inch slab on grade. The basement walls are reinforced concrete. For the most part, the two upper floors and the roof are 13 inch deep two-way ribbed slabs with 5 inch wide ribs at 24 inches on center. The ribs are 8 inches high leaving a top slab thickness of 5 inches. The ribbed slabs are supported on 26 inch diameter columns. Typically, the columns have 5 foot diameter capitals and the slabs have 14 foot square drop panels 4 inches thick. The typical bay size is 34'-0" in the north-south direction by 29'-0" in the east-west direction. The north end of the building is defined as the end of the building along Milk Street. The ramps and some isolated areas of floor and roof slab are constructed of solid flat slabs on beams.

Drains are provided at all levels. Typically, there is one drain for every four bays or 986 square feet. The slabs are pitched to drains. As shown on the original drawings, the roof slab is covered with a layer of bituminous concrete over the entire slab area. We do not know if a waterproofing membrane was placed between the top of the concrete slab and the bottom of the bituminous paving.

The entire garage is enclosed by exterior walls constructed of limestone panel ashlar backed up by sand lime brick or reinforced concrete. Typically the panels are about 3'-0" wide by 4'-8" high by 1-3/4 inches thick. At the roof level there is a 2'-6" high sand lime brick parapet with a limestone face and coping.

The structural drawings indicate that the structure was designed for the following live loadings:

<u>Level</u>	<u>Design Live Load (pounds per square foot)</u>
Roof	130
Second	100
First	150
Ramps	150

These drawings also indicate that the concrete for the superstructure was to have a strength of 2,500 pounds per square inch (psi) at 28 days. Footing concrete was to have a strength of 3,750 psi at 28 days. The reinforcing was to be intermediate grade deformed

bars. The original drawings called for the following concrete cover over the reinforcing steel:

<u>Member</u>	<u>Cover (inches)</u>
Slabs	1
Ribs	1-1/2 (bottom), 1 (sides)
Beams	1-1/2
Columns	1-1/2
Footings	3

Inspection Approach and Summary of Field Observations

On Friday, 24 February 1984, M. L. Brainerd visited the Boston Public Library, with Mr. Wallace Orpin of the Boston Redevelopment Authority, to review the original drawings for the garage. Subsequent to the drawing review, Messrs. Orpin and Brainerd conducted a limited inspection of the building. Based on this drawing review and site visit the following inspection approach was developed:

- Conduct a local level survey of the underside of the second floor slab in order to establish if drainage pitch is provided by topping placed over the structural slab or by local warping of the structural slab. If topping was not used, then hollow areas (delaminations) found on the top surface indicate that corrosion of the top reinforcing is occurring. If topping was used then delaminations found could be between the topping and main slab and this would not necessarily be indicative of reinforcing bar corrosion.
- Conduct a condition survey of the second floor slab. On the top surface document delaminations, cracks, patches, ponded water and construction joints. Also document spalling of the concrete at column bases. On the bottom surface document areas of spalled concrete and corroded reinforcing bar. Document areas of concrete that are cracked and about to spall. Attempt to determine the cause of deterioration and assess the degree of metal loss at corroded reinforcing.

- Using the second floor condition survey as a basis, conduct a limited qualitative visual inspection of the top and bottom surfaces of the first floor slab, and the bottom surface of the roof slab sufficient to permit a qualitative assessment of the structural condition of these slabs and the column bases.
- Conduct a limited visual inspection of the basement slab on grade and basement walls.
- Conduct a limited visual inspection of the bituminous topping at the roof. Visually inspect the parapet.
- Conduct a limited visual inspection of the entrance and exit ramps.
- Conduct a limited visual inspection of the building exterior.

On Sunday, 26 February 1984, F. J. Heger and M. L. Brainerd visited the site to conduct the structural inspection as outlined above. A summary of our observations follows (the Milk Street end of the building is considered north):

1. We performed a level survey of the underside of the second floor slab. With a level and rod we took ten level readings each along the D line and E line from the I line to the 4-1/2 line. The readings indicate that the slab soffit pitches from a high point along the E line toward the D line. The D line has drains at the 2 line and 3 line. The slab soffit along D line is lower than E line and is pitched toward the drains. Visual inspection of the top surface of the slab showed no evidence that a concrete topping layer was applied over the structural slab for drainage slope.
2. We performed a condition survey of the top surface of the second floor slab. At approximately 44 of the 58 interior columns, by striking with a hammer or dragging a chain, we sounded the surface of the slab at the column strip intersection areas. These areas are the areas of slab with two perpendicular layers of top steel corresponding approximately to the area over the drop panels. We detected hollow areas (delaminations) at all of the locations inspected. The delaminations range in area from about 5 square feet to 200 square feet, the complete column strip

intersection area. We noted bituminous patches at 21 of the 44 column areas inspected and at 6 of the column areas not inspected for delaminations. We found numerous bituminous patches at slab areas other than the areas immediately around the columns (Photo 1). We found some delaminated areas of slab along the exterior walls. We also noted some delaminations at column strip-middle strip intersection areas. These areas are areas of slab with a single layer of top steel centered on and running perpendicular to the column line, and located within the middle half of the span.

We found large flexural cracks running parallel to the column lines (Photo 2). These cracks are typical and most pronounced along the east-west (lettered) column lines. They occur to a lesser extent along the north-south column lines.

All columns showed some evidence of spalling at the bases (Photos 3 and 4). The degree of deterioration ranged from evidence of cracking and imminent spalling to exposed and corroded reinforcing steel.

Construction joints in the east-west direction are located approximately 10 feet south of H line, 10 feet south of G line, 10 feet north of E line and 11 feet north of C line. There is a construction joint in the north-south direction located approximately 11'-8" west of 3 line running between the north-south construction joints that are adjacent to the H and G lines. Another east-west construction joint is located approximately 9'-5" west of the 5 line running between the ramp wall and the north-south construction joint adjacent to the C line.

We noted about 400 square feet ponded water straddling the 3 line between the G and H lines. The surface of the slab in this area is lower than the drain near column H3.

3. We performed a condition survey of the underside of the second floor slab. Along the ribs we documented approximately 4,000 lineal feet of either spalled concrete and exposed corroded bottom reinforcing steel, or obvious cracking indicating imminent spalling (Photos 5 and 6). This represents about ten percent of the total length of rib at this level. Approximately ninety percent of this deterioration is

located along the construction joints. The remaining ten percent occurs randomly at locations of inadequate concrete cover over reinforcing bars or conduits in the ribs, or where cracks have formed at conduits in the top slab, thus allowing water to penetrate the slab and contact the ribs. Thirty bays, representing two-thirds of the typical bays, exhibit deterioration. We found some significant deterioration at the wide ribs and beams on the column lines (Photo 7). Typically this deterioration occurs along construction joints.

4. We conducted a limited visual inspection at the basement level. The slab on grade appears to be in fairly good condition with some minor cracking probably due to shrinkage. Pools of water are present around some of the column bases. Many of the round interior columns have spalling at the bases. This deterioration ranges from obvious cracks and imminent spalling to exposed and corroded reinforcing. The exposed reinforcing appears to have had inadequate concrete cover.

The basement walls appear in good shape with few cracks and no obvious signs of movement or distress.

The underside of the first floor, as at the second floor, has areas of spalled concrete and, exposed and corroded bottom rebar. As with the second floor the deterioration seems to be concentrated at construction joints. The extent of the deterioration at the first floor appears more extensive than at the second floor. The zone of deterioration at the construction joints is wider at the first floor and there are more areas of random deterioration resulting from water penetrating cracks in the top slab at conduits. Based on this limited visual inspection it appears that nearly all the typical bays at the first floor exhibit deterioration. The total length of deteriorated ribs appears to be about fifty percent greater at the first floor than at the second floor.

5. We conducted a limited visual inspection of the top surface of the first floor slab. At the time of our inspection the main parking area at this level was full with parked vehicles. Column strip intersection areas around four or five randomly selected columns were sounded with a hammer. All show evidence of delamination. The column bases appear to be in good shape with no spalling and only some

cracking. Bituminous patches are evident throughout, particularly at the entrance and exit areas where virtually the entire area is topped with bituminous. We noticed large flexural cracks, similar to those observed at the second floor, along some column lines.

6. We conducted a limited visual inspection of the underside of the roof slab. The underside of this slab is in very good condition with only a few isolated areas of minor deterioration.
7. We conducted a limited visual inspection of the roof level. The bituminous topping is in poor condition. Large patches and many cracks and ruts are evident. We found a few areas of standing water (Photo 8). The parapet is in poor condition with torn or missing base flashing, spalled brick and deteriorated mortar joints (Photo 9). Metal flashing is provided below the limestone copings but is bent and damaged in various locations. Caulked joints between coping stones are badly deteriorated. A section of the parapet around the northeast stair has recently been replaced.
8. We visually inspected the exit and entrance ramps. In general the ramps are in good condition; however, there are four small areas on the underside of the ramp slabs that are about to spall (Photo 10). We found a crack in the top of the concrete beam that supports the roof slab and ramp exterior wall on A1 line. This crack is over the northernmost column on A1 line (Photo 11). The concrete corbel that supports the roof slab at A line just west of 6 line on the wall between the up and down ramps is cracked (Photo 12).
9. We walked around the outside of the building to visually inspect the exterior. There are numerous locations where the limestone ashlar ties have corroded and expanded, resulting in spalling at the edges of the panels (Photo 13). We found a few locations where outward movement of the limestone panels has occurred (Photo 14). The northeast corner of the concrete canopy on I line between A1 line and C line is damaged. It appears that it may have been hit by a truck. Many of the metal sills and heads at the windows are buckled.

Discussion

Parking deck slabs are exposed to significant quantities of de-icing salts due to the melting of snow and ice on entering and parked vehicles. The salt-laden water permeates the uncracked areas of the top surface of the slab. Cracks allow the salt-laden water to flow more rapidly through the slab where it then permeates the bottom surface of the slab. The chlorides deposited at the reinforcing lower the pH and set up electrical potentials at the bar surface. This condition results in galvanic corrosion of the reinforcing steel. The corrosion produces corrosion products which have greater volume than the original stable metal. This expansion of the reinforcing steel volume produces bursting tensile stresses within the concrete, causing delamination and eventually spalling of the concrete cover over the reinforcing. Delamination is an indication that the corrosion is at an advanced stage and that spalling is imminent. Once delamination begins, air, moisture and chlorides can more easily attack the bar surface and the deterioration process accelerates.

The size and number of delaminated areas documented on the second floor together with the fact that all of the areas sounded on the first floor showed signs of delamination leads us to conclude that much of the top steel at the first and second floors is in the advanced stage of corrosion. We believe that most of the top steel is corroded to some degree. The areas that have been patched with bituminous were probably at the spalling stage when repaired. Removing the spalled concrete and patching with bituminous creates a more serviceable surface but does not stop the deterioration. In fact, the bituminous can aggravate the situation by trapping the water at the reinforcing surface. The deterioration of the top surface of the first and second floor slabs is a serious structural concern. The corrosion of the reinforcing bars reduces the area of the bars but more importantly the build-up of corrosion product around the bars, and the delaminating and spalling of the concrete destroys the bond between the bars and the concrete. Without this bond the reinforcing is ineffective.

The spalled concrete and corroded reinforcing at the bottom of the slab is due primarily to direct attack by salt-laden water flowing through the construction joints. Typically at these joints, the ribs on each side of the construction joint as well as a three to four foot width of the ribs perpendicular to the construction joint are severely deteriorated

(Photo 5). Most of the construction joints are in locations where shear and positive moment are less than maximum; however, the deterioration has severely reduced the shear and moment capacities of these members. At bays with construction joints, the capacity of the slab span in the direction perpendicular to the joint is greatly reduced since all of the ribs in this direction are deteriorated at the joint. At the second floor 30 of the 45 typical bays are crossed by construction joints. All of these bays are deteriorated at the joint, most of them severely.

The first floor underside appears to be even more severely deteriorated than the second floor. While, as at the second floor, there is severe deterioration at the construction joints, there are also many areas that are severely deteriorated due to direct attack of salt laden water flowing through cracks at conduits in the top slab. Typically these areas are at the corners of drop panels, in areas of high shear. The reduced shear strength of the ribs at these locations is a structural concern.

The bottom surface of the roof slab is in good condition even at construction joints. This leads us to conclude that there is probably a waterproofing membrane on the top surface of the slab between the slab and the bituminous paving. No such membrane is shown on the original drawings. Due to the presence of the paving, we were not able to sound for delaminations on the top surface of the roof slab; however, given the good condition of the underside of this slab we feel that the top surface is probably in good shape also.

The deterioration of the column bases is due to permeation of water through the inadequate concrete cover over the reinforcing steel. This deterioration reduces the load carrying capacity of the columns. As yet, this strength reduction is probably not large, but deterioration will increase at an accelerated rate without remedial repairs.

The imminent spalling at isolated areas of the ramp slabs occurs in a direction parallel to the slab span and is, as yet, not a cause for concern about the structural adequacy of the ramps. The cracks in the corbel and beam are medium sized and indicate some degree of distress; however, they are not cause for immediate concern about the structural safety of these areas.

The roof parapet, while unsightly, does not show signs of significant movement or instability. Without remedial repairs, however, the extensive torn flashings, cracked brickwork at the back of the parapet and dried out caulking of the coping stone joints will result in an accelerated rate of deterioration.

The spalling of the limestone ashlar panels at anchor locations indicates that the anchors are corroding. This situation is a cause for concern since failure of these anchors will result in the panels falling off the building if loosened by thermal or wind loads. There is presently evidence of some panel movement (Photo 14).

We have not performed calculations to verify the adequacy of the deteriorated structure, as this is beyond the scope of this report. The original drawings indicate that the structure was designed for live loads in excess of the 50 pounds per square foot requirement for passenger car parking garages in the current Massachusetts State Building Code. The deterioration, however, of the first and second floor slabs is so severe and so extensive that the safety of these slabs is questionable even in view of the excess structural capacity indicated by the original design live loads.

Conclusions

- I. The garage has serious structural deterioration and requires major repairs to remain in service. During our limited condition survey we observed deterioration that significantly reduces strength and durability in the following areas:
 - I.1 **First and Second Floor Structures.** The ribs of these slabs have lost much of the concrete in their stems and bottom reinforcing is exposed and severely corroded at all construction joints, and at some other randomly located areas, often adjacent to the solid concrete panels at columns, where salt-laden water has penetrated cracks. The tops of these floor slabs have extensive areas of delaminated (hollow sounding) concrete cover over top reinforcing, along with numerous bituminous concrete patches where the original surface concrete is already gone. This condition makes it very probable that top reinforcing is also corroded in large areas of these floors.

The observed deterioration in the ribs and at the top surface of the floors is so extensive as to cause concern about the structural adequacy of the existing floors in the deteriorated areas. Without remedial measures, deterioration will continue at an accelerating rate.

- 1.2 **Column Bases.** We observed extensive cracking and spalling of concrete cover over reinforcing in the lower 6 to 18 inches of numerous columns. Reinforcing is exposed and corroded in a few of these columns. Most of the columns above the basement floor and the second floor exhibit this spalling, while it is less prevalent in columns immediately the first (street) floor.

The observed deterioration at column bases has already caused some reduction in column strength, but probably is not yet a structural safety problem. The major concern is that deterioration will continue at an accelerating rate and eventually the column could become unsafe.

- 1.3 **The Limestone Ashlar Panels.** These panels that form the exterior walls of the garage exhibit local spalling. These spalled areas are probably anchor locations, and the local spalling indicates that the metal anchors are probably corroding. Failure of these anchors would result in panels falling from the building.

- 1.4 **Ramp Areas.** Only local regions in the ramps show cracks, spalling and some reinforcement corrosion. This distress is not cause for immediate concern about structural safety. Repairs are needed to preclude spread of deterioration beyond the existing local areas.

2. We also observed major deterioration of the parapets around the perimeter of the roof. This includes extensive lengths of torn up metal cap flashing at the inside of the parapet base, cracking and deterioration in brickwork on the inside surfaces of parapets, some tearing of metal flashing under coping stones, a few damaged coping stones, and extensive deterioration of caulked joints between coping stones. The bituminous paving on the roof is extensively cracked and rutted.

3. The reinforced concrete roof slab is in very good condition, apparently having been protected by waterproofing membrane below the bituminous paving of the roof parking level.
4. Overall, the garage requires extensive repairs and renovations as follows:
 - 4.1 Reconstruct deteriorated portions of first and second floor ribs and top slab surfaces.
 - 4.2 Restore cover concrete at most round column bases.
 - 4.3 Improve drainage in a few bays at roof, second, first, and basement floor slabs.
 - 4.4 Restore watertight integrity and durability of parapets.
 - 4.5 Restore aesthetics, and water and vehicle impact protective functions of exterior walls.
 - 4.6 Modernize lighting, toilet facilities, and security throughout garage.

Recommendations

If the building is to continue in service, the following general remedial construction probably is required:

1. Restore structural integrity. This probably requires removal of 1-1/2 to 2-1/2 inches of surface concrete over the entire first and second floor slabs, addition of new top reinforcing steel, where existing steel is corroded, and a new topping layer of dense concrete.

In areas where ribs have suffered severe loss of concrete from their stems, or where the stems are severely cracked or deteriorated and the bottom reinforcing is severely corroded, the entire area of deteriorated slab should be removed and

replaced. We estimate that 15 to 20 percent of the first and second floors would have to be cut out and replaced. In some local areas, cracked and partially spalled concrete protection should be removed, and where reinforcement has not lost excessive amounts of metal, new cover mortar should be applied over an epoxy bonding agent.

Cracked and spalled concrete cover in the base area of columns must be cut out down to sound concrete, badly corroded reinforcing replaced, and new cover concrete or mortar applied to restore the durability and integrity of the columns.

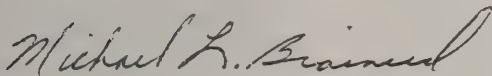
2. The cracked and rutted bituminous concrete pavement at the roof level should be removed and replaced. Removal of this pavement will probably damage the membrane waterproofing layer that has protected the roof slab, so that this membrane will have to be replaced along with the bituminous paving. A liquid applied traffic membrane could be used in lieu of new waterproofing and bituminous concrete to obtain lower first cost, but it would have a shorter life and probably require more maintenance than a pavement protected membrane.
3. The parapet should either be removed and replaced with a safety rail barrier, or it should be extensively renovated to prevent entry of water and deterioration of masonry, and to provide an adequate barrier against vehicle impact.
4. The exterior of the building requires complete reconstruction to improve aesthetics, remove potentially hazardous limestone panel anchors (that probably are corroded), remove deteriorated metal windows and restore weather protection, if the garage continues as a fully enclosed garage. Alternatively, a reconstructed enclosure could be a screen wall that provides only aesthetic and vehicle impact barrier functions without weather protection.
5. The electrical, mechanical, and security systems in the garage should also be reconstructed, consistent with the extensive structural and architectural reconstruction described above. Evaluation of these existing systems was not within the scope of our structural condition survey. Floor drains should be added where

water ponds at existing low points in floors. This will require removal and reconstruction of some basement slab on grade.

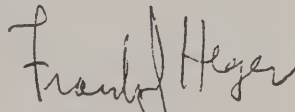
The structural deterioration that we observed at the first and second floor slab is serious enough to warrant our strong recommendation that the organization with responsibility for the garage facility (i.e. Owner, or Leasee, we presume) should commission a comprehensive structural review of the garage to ascertain whether it is safe to keep in operation without temporary strengthening of the deteriorated areas of the first and second floors. This investigation should also determine whether the metal anchors that hold the limestone ashlar panels on the building still have adequate strength.

Respectfully submitted,

SIMPSON GUMPERTZ & HEGER INC.



Michael L. Brainerd
Senior Staff Engineer



Frank J. Heger
Senior Principal

MLB/FJH/ct(1-84)



PHOTO 1

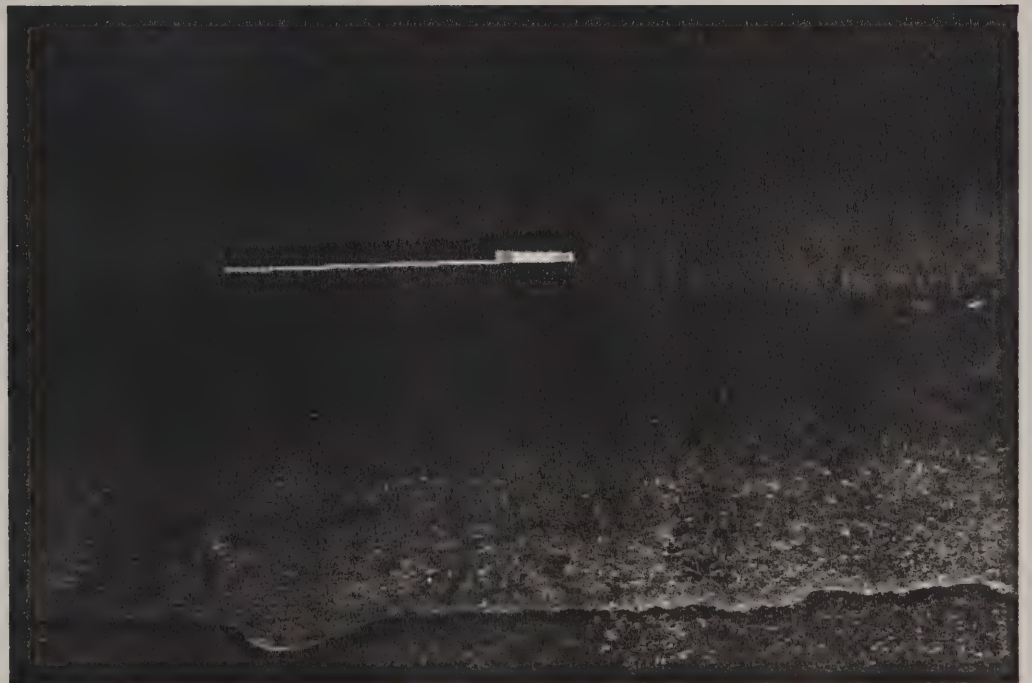


PHOTO 2



PHOTO 3



PHOTO 4



PHOTO 5

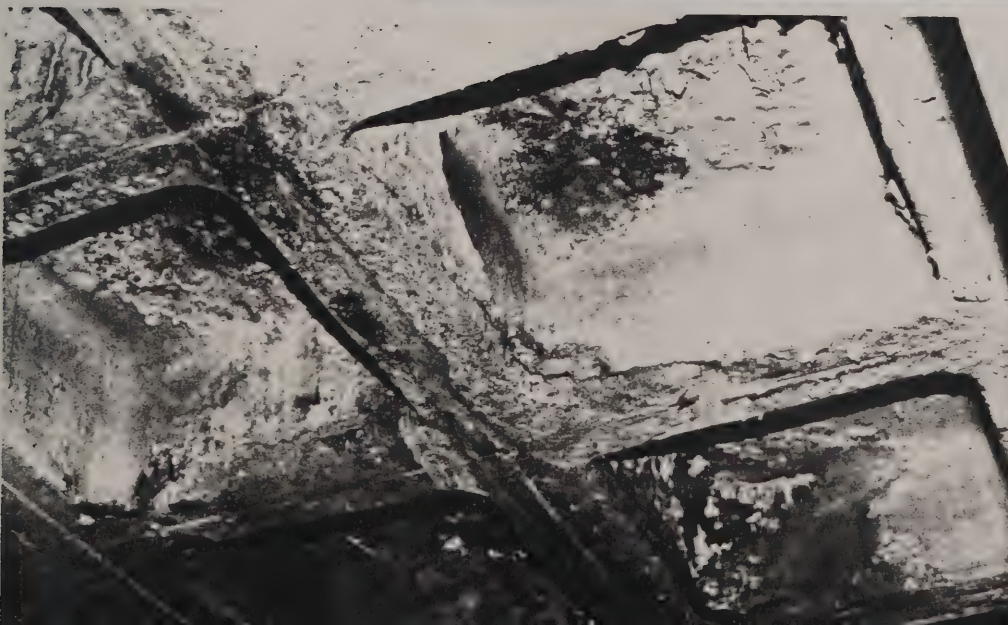


PHOTO 6



PHOTO 7



PHOTO 8

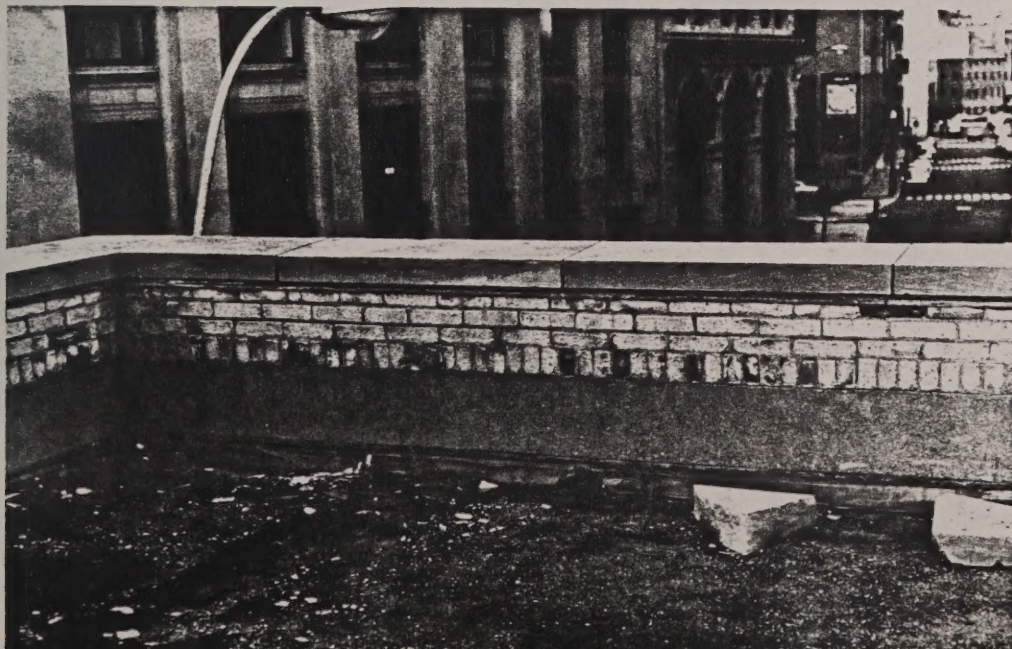


PHOTO 9



PHOTO 10



PHOTO 11

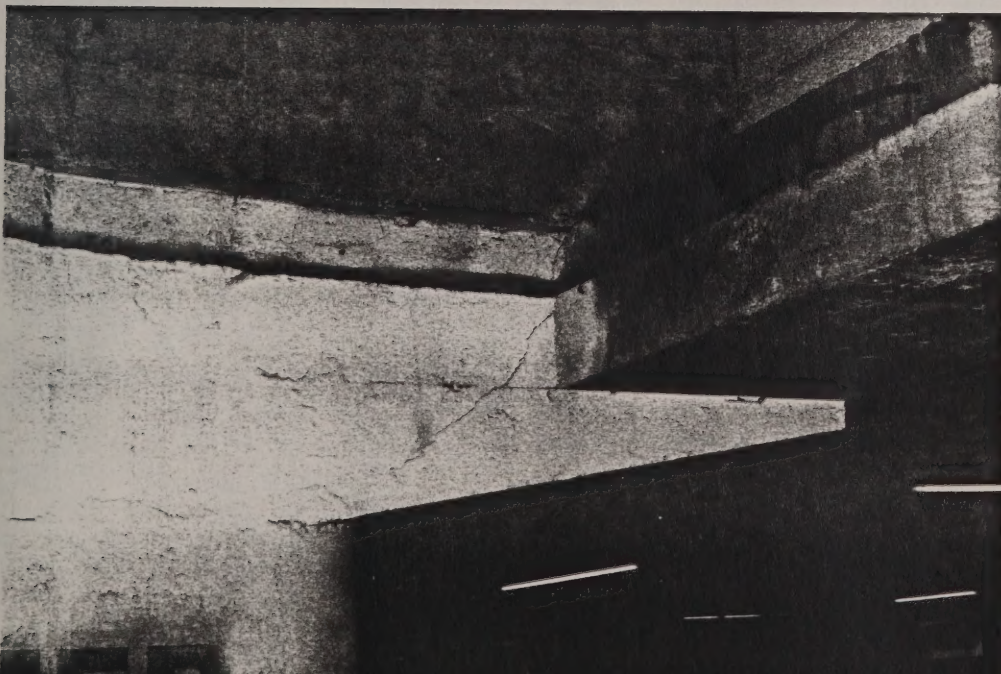


PHOTO 12



PHOTO 13



PHOTO 14

